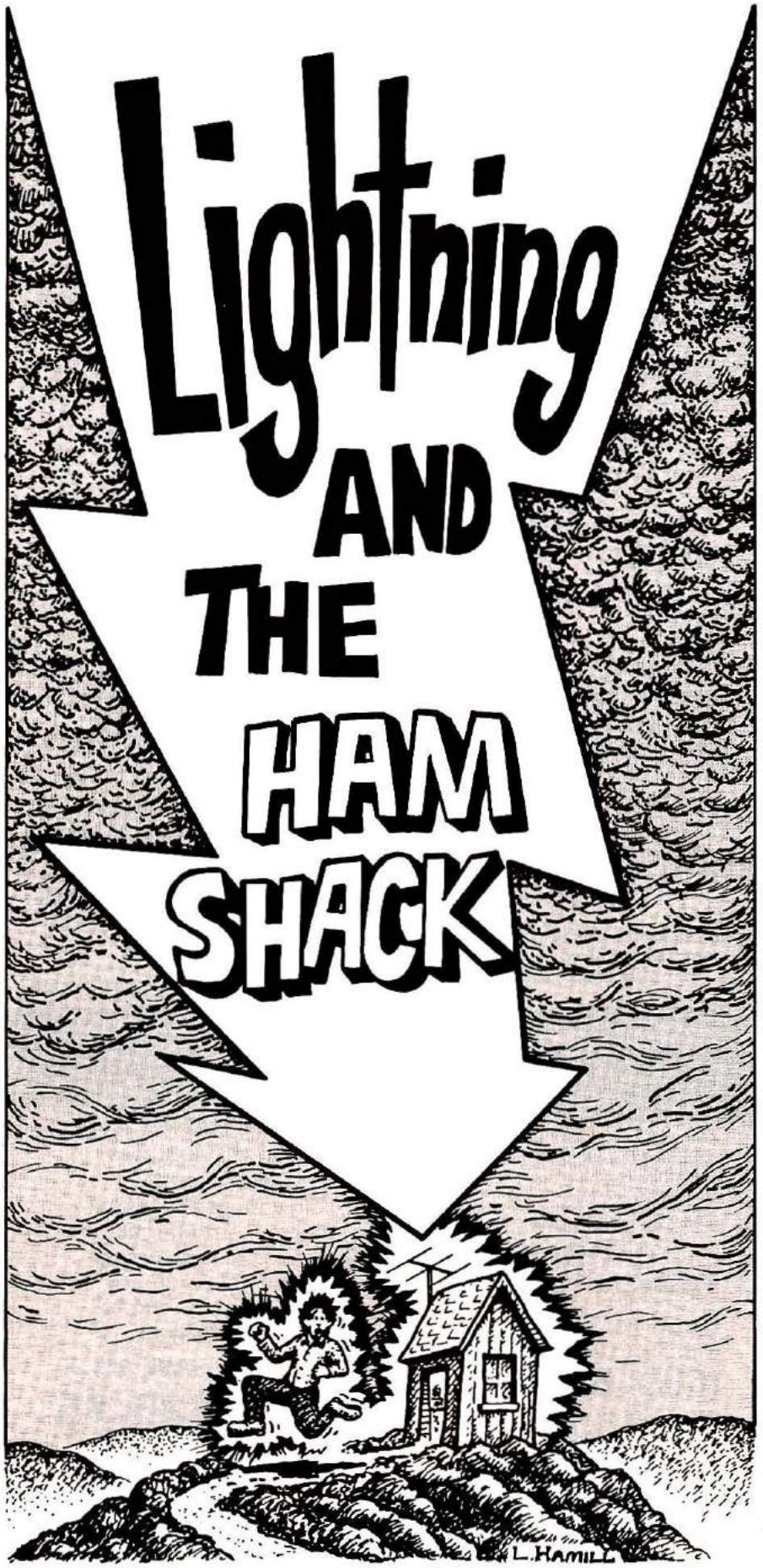


BY KARL T. THURBER, JR., W8FX

If you check your encyclopedia or dictionary, you'll find that lightning is a natural high-voltage discharge or electrical spark, usually a few miles long, that takes place in the earth's lower atmosphere. The American scientist, Ben Franklin, was the first to correctly identify lightning as an electrical discharge through his famous kite experiment in 1752.

How lightning works

These discharges may take place in thunderstorms, either between nearby clouds or between the clouds and the earth. Before the discharge, the clouds build up an increasingly strong electrical potential with respect to adjacent clouds or the earth by gradually accumulating charges through the effects of falling snow or rain. Potential differences, or voltages, of several million or even as much as *one billion* volts may develop — and the discharge may produce transient (very brief) currents up to 100,000 or 200,000 amperes!

The very high voltage buildup arises because of regions of highly charged particles developing within the clouds: negatively charged regions generally developing near the bases and positively charged areas near the tops. The intense fields created cause surrounding molecules to become *ionized*, and the lightning strokes attempt to equalize the potential by moving along the highly conductive paths between these oppositely charged regions. Usually, this happens within a cloud but often occurs from cloud-to-cloud or from cloud-to-ground. When this happens, we see visible lightning.

Thunder is the audible sound wave generated by the lightning stroke. The sound of thunder appears to lag behind the lightning because of the relatively slow speed of sound compared with that of light;

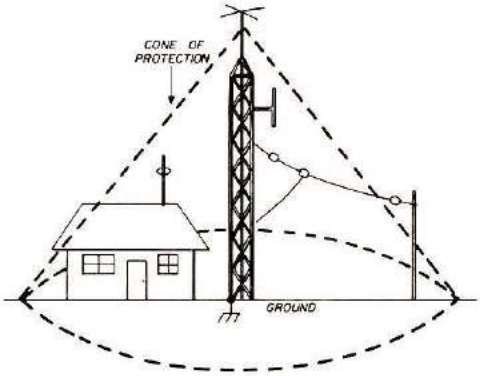


Fig. 1. Dramatization of the theory that a properly grounded antenna and tower can create a "cone of protection" around nearby buildings and other structures, which shields them from lightning damage. The diameter of this cone is said to be equal to tower height (drawing is not to scale).

first you *see* the lightning and then you *hear* it.

You can see and hear the result of many different forms of lightning such as sheet, ribbon, bead, and ball lightning. Each of these types produces unusual and often spectacular visual effects. As amateurs, we're usually concerned less with the visual displays than with the effects that lightning can have on our equipment and homes, which brings us closer to the heart of this article.

Why is lightning so dangerous

Ninety percent of lightning discharges are of the intra-cloud type; the discharge harmlessly occurs within a cloud. This kind of lightning doesn't cause much of a problem. But when lightning seeks its path through the earth, its power to destroy is indeed awesome. Each year, lightning kills or injures several hundred persons in the United States and causes more than 10,000 fires.

The lightning discharge, packing currents as high as 200,000 amperes, reaches its peak usually in less than 80 microseconds. The discharge declines only slightly less rapidly, normally in less than 200 microseconds. Very common, too, are multiple strokes, with up to 40 discharges extending over periods up to a full second. Although the discharge peaks out and is over in a fraction of a second, that short period of time is long enough for the high current generated to exact its toll on buildings, trees, poles, houses, antennas, a-c lines, and anything else in its path.

Glossary of Terms

Balun is a device that provides a transition between an unbalanced (to ground) feedline, such as coaxial cable, and a balanced line or antenna, such as twin-lead or a dipole. Balun derives from *Bal*anced-to-*Un*balanced.

Grounding Circuits are used to dissipate unwanted electrical energy into the earth. Protector grounds for communications circuits need to be no more elaborate than the familiar water-pipe ground, providing that ground resistance is minimized. Ground resistance decreases with the number of ground rods, their diameter, and material makeup. Ground resistance also decreases with the depth of driven ground rods and varies with soil conductivity, which may change with the seasons.

Ionization is the process by which one or more electrons are added to or removed from an atom. When lightning occurs, the tremendous force created by the electrical discharge changes the atomic structure of the immediate atmosphere so that its natural balance is temporarily disturbed, thus ionization is said to occur.

Low-Impedance Ground is essential for circuits that require a direct route to earth (or ground). Impedance is the opposition in an electrical circuit to the flow of an alternating current. Impedance is analagous to the electrical resistance of a circuit to direct current.

Feedthrough tube for bringing coaxial cable into a building. The metal bracket should be grounded using a length of no. 10 (2.6 mm) or larger wire to a ground rod.

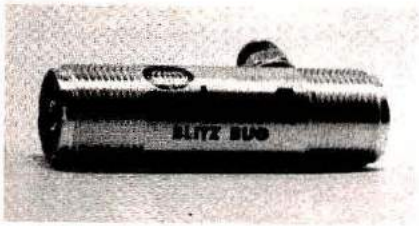
Tall buildings and towers can induce lightning discharges, as can aircraft flying through storms. However, a so-called cone of protection sometimes exists around a structure (such as a house), which is overshadowed by a taller antenna tower or mast (**Fig. 1**). Observers of lightning strikes on antenna towers have noticed that an electrical leader sometimes appears to originate in and around the top of the tower, traveling upward into the cloud, with its streaked fingers pointing upward rather than downward, as is usually the case in lightning discharges to ground.

Contrary to the old wives' tale that lightning never strikes twice in the same place, lightning will, in fact, show an affinity for striking the same point or object if the object hasn't been removed. Actually, this makes sense because the object that attracts the lightning discharge in the first place probably has a high, prominent position.

The lightning discharge core diameter is only 25 to 50 millimeters (1-2 inches), while the strongly electrified area surrounding this small core is probably several meters (feet) in diameter. In any case, lightning is dangerous to you and your equipment! The average lightning discharge involves a potential difference of 100-million volts, packing nearly 300 kilowatt-hours of energy — enough to make anyone consider its potential for damage!

Protecting your antenna

The kind of damage and havoc caused by lightning to



Coax-cable lightning arrester known as the "Blitz Bug." Device contains a spark gap through which lightning discharges may be bled to ground (*photo courtesy Cushcraft*).

amateurs whose antennas or towers have been struck by lightning doesn't mean that an outside antenna invites disastrous consequences during electrical storms. A properly installed and grounded antenna system creates a "cone of protection," whose diameter is approximately equal in height to the antenna itself. Many amateurs have operated for years with antennas that were the highest objects in the vicinity without lightning damage. **Fig. 1** shows this cone of protection. The tower offers some protection to nearby lower buildings and structures, but only when it has a good, direct, *low-impedance ground*.

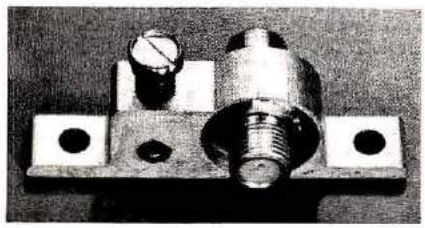
If there's a secret to protecting antennas, towers, and your station, it's in providing a direct path from the antenna to ground so that the electrical charges picked up from the atmosphere during an electrical storm will be discharged harmlessly to the earth, rather than cutting a swath through the radio equipment and transmission lines. Bear in mind that the main purpose of installing lightning rods or of grounding roofs and other tall structures is to protect the building if a strike occurs; and while the tower may provide some sort of cone protection, no one has yet determined that any form of protection can *prevent* a lightning strike.

Protection from lightning

For good antenna protection there are a number of things you can do. First, you should ground all towers, including structures mounted on roofs or atop buildings. Metal towers are usually well grounded; but with wooden towers, you should run a *heavy* ground wire to the hardware on top of the tower supporting a horizontal antenna. If the horizontal antenna is all that the wooden tower supports, extend this wire above the level of the antenna so that it acts as a lightning rod. A commercially available lightning rod, such as those installed on barns and rural dwellings, can also be used. Not to be forgotten is protection for the ground-plane antenna. When this antenna is elevated above the ground, be sure to run a *direct* ground wire to its radial system. Don't rely on the coax shield to provide grounding and lightning protection.

Even with the vertical that's ground-mounted ("worked against ground"), there is a difference in the ground systems for lightning protection and for rf grounding purposes. The former uses long ground rods buried deeply into the earth; the latter uses a number of radials buried a few inches below the earth's surface. For good lightning protection, ground rods should be connected at the center of the radial pattern. Installing additional ground rods at the radial ends won't hurt, either, for added protection.

Tower-mounted rotary beams using either T or gamma matches, and having each element connected to the boom, can be grounded through the supporting metal tower in most cases. From a protection standpoint, it's a good idea to run the coax and rotator control lines from the antenna down inside the metal tower, then underground to the station if possible.



Another form of coax-cable lightning arrester. The assembly must be grounded using heavy copper or aluminum wire (*photo courtesy Radio Shack*).

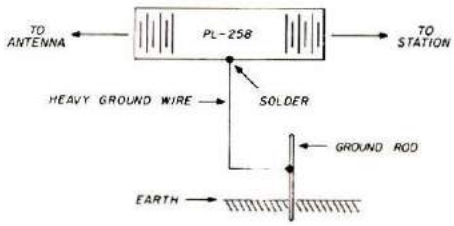


Fig. 2. Coaxial-cable feedthrough connector for lightning protection can be made from a type PL-258 device. It should be inserted into the coax cable before the cable enters your station and the outer shell must be connected to a good earth ground.

Unfortunately, grounding a multiband trap antenna (whether horizontal or vertical) at the feedpoint doesn't adequately protect the traps from damage during a lightning strike; sometimes induced currents from nearby discharges may cause damage. It's possible to construct a wire spark gap across the traps, but this is likely to detune them and otherwise upset their operation. From a practical standpoint, traps can remain unprotected and are best replaced if struck.

Watch that transmission line!

Although the antenna may be well grounded, the transmission line can be struck by lightning and cause damage to your house or equipment if not protected. The best place to protect the coax line is where it enters the building. You can install a type UG-363/U or 83-1F coax bulkhead adapter on a sheet metal bracket on the outside of the building where the cable enters, either through a wall-through tube or window. The metal bracket should be grounded using a length of no. 10 (2.6mm) or larger wire to a ground rod. You can also

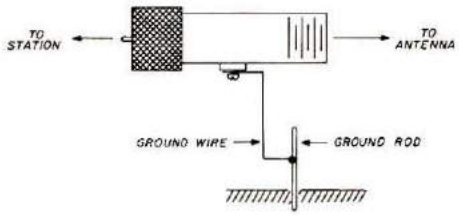


Fig. 3. Representation of a typical commercially available lightning arrester manufactured by Amphenol, Cushcraft, and others. When installed outdoors and solidly grounded it will protect equipment from lightning damage through antenna and transmission line. Various combinations of male and female connectors are available.

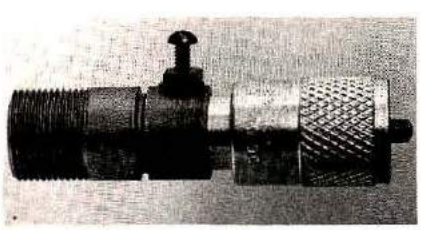
fabricate your own self-grounding feedthrough connector using an Amphenol 83-1J (PL-258) connector — the kind used to splice coax sections together — by soldering a heavy ground wire to it and mounting it outdoors at a convenient spot as shown in **Fig. 2**.

The bulkhead adapters aren't easy to find these days, and you may not want to roll your own. A much easier method is to install a commercially made static discharge unit or lightning arrester in the feedline where it enters the building. These units contain a small spark gap that won't arc or short out at normal power levels used by amateurs but will allow all high-voltage discharges to bridge the gap and be diverted to ground. A number of manufacturers make these handy gadgets, which are available from Cushcraft, Radio Shack, Hy-Gain, and Amphenol (**Fig. 3**).

While nothing can guarantee complete protection from a direct lightning strike, these units can head off problems from nearby lightning discharges that might induce high voltages and currents into your transmission line (which can damage receiver front ends and transmitter tank circuits) by bleeding off the charges to ground. For added protection, you can mount one arrester near the antenna or on the tower and another near the entrance point to your station.

You should be aware that if the antenna is at dc ground potential — as is the case with a gamma-matched beam — the arrester isn't strictly necessary. You need only ensure that the coax shield is grounded at the tower and where it enters the house or station. Normally, grounding the shield at this point won't have any effect on the line's performance so long as you're not trying to operate with a very high standing wave ratio. If you *do* operate with a high swr, introducing an additional grounding point may change the effective swr presented to the transmitter. In any case, as previously mentioned, installing lightning arresters is simple and offers some extra protection against stray static electricity.

While coaxial cable is the most popular transmission line in use today, open-wire line or twin-lead can also be protected, as shown in the arrester circuit of **Fig. 4**. Don't try to use a TV-type lightning arrester except for very low power levels. In any case, you'll find that coax is a lot easier to work with than parallel-wire feeders. But if you want to use a folded dipole or other antenna that requires a balanced 300-ohm feedline, consider using a 4:1 impedance-matching balun mounted at the antenna. The balun, or balanced-to-unbalanced transformer, converts from the unbalanced coax to a balanced output by transformer action. Most baluns put the antenna at dc ground potential, offering a degree of built-in lightning



A coax-cable lightning protector made from male and female connectors. The shell must be grounded using heavy wire run to a ground rod.

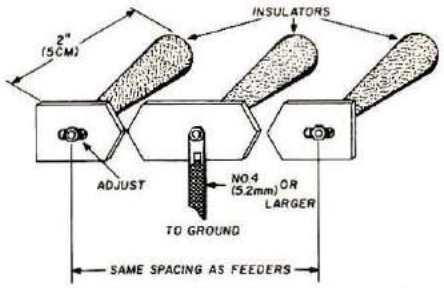


Fig. 4. Lightning arrester for parallel-conductor feedlines. It can be made from three feedthrough or standoff insulators and three sections of copper or brass strap material. It should be installed at a point convenient to the antenna tower or main outdoor ground, preferably close to where the feedline enters the station. The spaces between the straps can be adjusted so that arcing doesn't occur in normal transmitter operation. The idea is that lightning discharges will shoot the gap and pass to ground.

protection. You can easily build your own baluns from details given in the *ARRL Handbook*, or you can purchase them readymade and waterproofed from Palomar Engineers, Kaufman Industries, Greene Insulator, and several other manufacturers.

Ground it!

There's an old radio axiom that says, "When in doubt, ground it." Nothing could be more true when it comes to effective lightning protection. But not just any old ground will afford good protection. For example, the main ground conductor shouldn't be any smaller than no. 8 or 10 (3.3 or 2.6mm) wire and should be copper, bronze, aluminum, or copper-clad steel. While the ground lead may be either insulated or bare, or even heavy copper braid, it should be protected from mechanical injury (lawnmowers, digging, gardening) and should go to the ground electrode or rod through the shortest possible path with no sharp bends. If bends are in the ground run, the heavy current flowing through the wire during a lightning strike may ionize the air at the bend and jump the conductor at that point to seek

its own shortest path to ground — leaving your equipment unprotected.

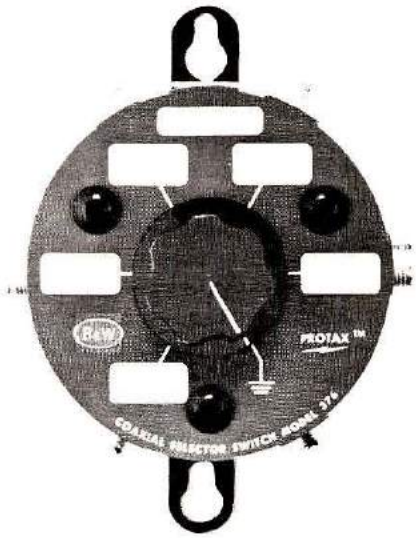
You can use a metal underground water pipe for the ground electrode, regardless of its length. It's a good idea to supplement the water pipe with a ground rod or electrode, which can be a galvanized iron, steel, or copper-clad pipe at least 19 mm (3/4 inch) in diameter; or you can use a 13 mm (1/2 inch) solid copper rod or other sturdy ground electrode driven into the earth at least 2 meters (6-8 feet). The rod can replace the water-pipe ground if the latter isn't conveniently available.

If your soil is dry and sandy, for best protection you should use at least *two* ground rods spaced at least 2 meters (6 feet) apart and bonded together by heavy wire or copper ground braid. Whatever arrangement you use to make a good ground, all grounds should be *bonded together* (paralleled) to lower the ground resistance as much as is possible. Doing this will also improve the performance of any vertical antennas you may use which are worked against ground. This is true because, by making your connection to ground better (lowering its dc resistance), you also lower the rf ground resistance and present the vertical antenna with a much better mirror or ground plane in the form of the Earth.

As for materials, inexpensive TV-type grounding hardware is probably the lowest-cost source. The heavy no. 8 or 10 (3.3 or 2.6mm) aluminum wire sold for grounding TV antennas is good, as are TV-type ground clamps. Be careful, however, in using the standard TV ground rods, as they are usually shorter than they should be to be really effective. If you can't locate longer rods, you can drive several of the shorter TV-type rods into the ground, spaced 2 meters (6 feet) or so apart, bonding them together as one ground — as in the case with sandy soil mentioned earlier.

Saving the station

Besides the potential for physical damage to your home (or possibly its total loss), even a nearby strike that leaves the home intact can wreak havoc with your ham gear. For example, some tubes, transistors, and integrated circuits can be destroyed from the effects of nearby lightning



Coax-cable selector switch for transferring your equipment to different antennas. Control knob should be set at the ground position when not in use (*photo courtesy Barker & Williamson*).

discharges. Capacitors and diodes, particularly those in antenna or power-supply circuits, can blow; receiver and transmitter antenna coils can melt or fuse; and contacts on rf switches can become welded together. Not infrequently, the rotator and rotator control box can be wiped out, and electrical fixtures and house wiring can be reduced to a sickening shambles.

There are a number of things you can do inside your station to minimize the chances for such unspeakable things to happen to your equipment. For example, to be safe, you should connect *all* microphones, key leads, metal cabinets, control boxes and shielded cables to a common ground bus, or wire, which, in turn, should be connected to the main station ground system (cold water pipe, ground rods) and the house's electrical ground system. Use an ohmmeter or multimeter set on a low-resistance scale to check that station grounds are *actually* connected to one another. If your home uses the three-terminal wall outlets that have the third wire grounded, use three-wire power cords whenever possible, which *automatically* ground all the equipment chassis and cabinets whenever the power plugs are in the wall sockets.

Lightning in the ac mains

While you may have done all you possibly can in protecting your antenna system and grounding your equipment, there's still another problem: the very real possibility of lightning surges on the ac power mains, which may enter your distribution transformer and be coupled to the ac circuit serving your home, even though the power company may have installed lightning arresters on the primary circuits. There's not much you can do about this problem, although you can buy 115-Vac lightning arresters and have them installed in your service line. From a practical standpoint, the best bet is to *remove* all of your equipment from the ac lines whenever a storm is brewing; or better still, disconnect them whenever you're not using them. This can be done be either physically removing the ac cords or switching them out of the ac lines using heavy double-pole, single-throw switches.

Needless to say, any piece of gear you value should be fused in its ac circuitry — or, as a minimum, you should have a special master fuse switch or circuit breaker for the station equipment. (Clocks and other equipment that require power at all times will have to be left connected.)

When storms are imminent

Another axiom is that during a storm, the only safe conductor is a grounded

conductor. This means that antennas should be disconnected and grounded whenever a storm is developing. It's a good idea to purchase an antenna selector that automatically grounds all the antenna positions except the one in use. Just turn the antenna selector to an unused position whenever you're not on the air. For a few dollars more, you can buy a coaxial switch that has an extra position that grounds *all* antennas (Barker and Williamson's Model 376 *Protax* coaxial selector switch is an example).

An example of what can happen

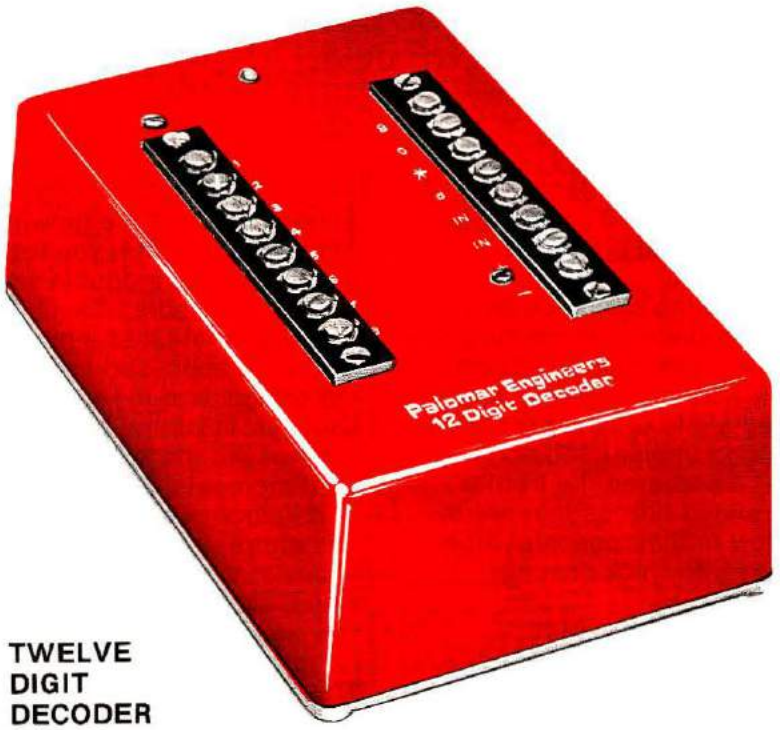
A gruesome example of what lightning can do to your station is shown by what happened several years ago to a Midwestern amateur when lightning took a fancy to his station, which suffered a direct hit.

Lightning destroyed the pole supporting his rhombic antenna, and caused all the wire in the antenna to vaporize. Since he had, fortunately, disconnected and grounded all his antennas, the rf stages of his receiver and the transmitter tank circuits weren't damaged, but the stroke packed enough power to knock the ac-power pole transformer to the ground! All ac supplies that were left connected to the mains were burned out (unless they happened to be fused in *both sides* of the line), and *all* the ac wall outlets in the house and most of the electrical wiring were damaged. As if this weren't enough, many of the switch and relay contacts in various household appliances were either burned out or fused together!

Though fortunately a rare incident, this sobering experience illustrates the tremendous potential for damage that lightning possesses. While nothing you can do will guarantee 100 per cent protection from lightning's destructive effects, following a few simple precautions is very cheap insurance.

HRH

Touch-Tone Decoders



TWELVE DIGIT DECODER $125.00

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- Decodes one Touch-Tone digit.
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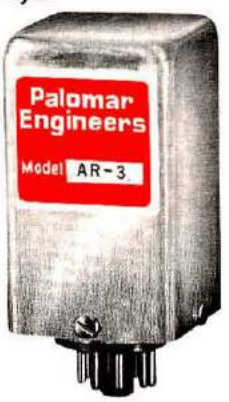
- Relay output SPST ½ amp.
- Operates on any DC voltage +12 to +30 volts.



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